

***Fletcher, Heald & Hildreth, P.L.C.***  
***1300 North 17<sup>th</sup> Street 11<sup>th</sup> floor***  
***Arlington VA 22209***  
***703-812-0400 (voice)***  
***703-812-0486 (fax)***

MITCHELL LAZARUS  
703-812-0440  
LAZARUS@FHHLAW.COM

July 25, 2001

Ms. Magalie Salas, Secretary  
Federal Communications Commission  
445 12th Street SW  
Washington DC 20554

**Re: ET Docket No. 98-153**  
**Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband**  
**Transmission Systems**  
***Ex parte Communication***

Dear Ms. Salas:

XtremeSpectrum, Inc. (XSI) responds to *ex parte* submissions by the U.S. GPS Industry Council (GPSIC) on May 22 and June 21, 2001.<sup>1</sup>

**The attached paper establishes that a properly regulated ultra-wideband (UWB) system will not cause harmful interference to a GPS receiver operated either outdoors or indoors as part of a handset-based E911 system.**

To protect GPS, as well as other services, XSI has suggested four regulatory measures more stringent than those proposed by the Commission:

1. an emission mask which rolls off more steeply below 2.7 GHz than the Commission's proposal;<sup>2</sup>

---

<sup>1</sup> Pursuant to Section 1.1206(b)(1) of the Commission's Rules, I am electronically filing this written *ex parte* communication for inclusion in the above-referenced docket.

<sup>2</sup> The NPRM suggests 12dB under Class-B below 2 GHz. *See Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, 15 FCC Rcd 12086 at para. 39 (2000) (NPRM).

2. a restriction to indoor-only operation;<sup>3</sup>
3. a test to reduce spectral lines in the GPS band;<sup>4</sup> and
4. an improved measure of peak-to-average ratio.

Taken together, these steps will fully protect GPS.

Additionally, we respond to specific concerns raised by GPSIC as follows.

- **There is little aggregate effect from multiple UWB devices**, even when they are concentrated in a small area. Because signals from indoor UWB devices cannot penetrate far, they cannot add over distances greater than about 10 meters. Moreover, devices operating within about 10 meters of each other must reduce power, percentage of time operating, or both in order to avoid UWB-on-UWB interference. *A GPS receiver sees less interference from an office building that contains hundreds or thousands of UWB emitters than from 2.5 full-time UWB emitters at the same distance as the nearest emitter.*
- **The emissions limits ("spectral mask") proposed by XSI are appropriate and sufficient to protect GPS.** It makes no difference whether the emissions regulated by the mask are deemed to be "intentional" or "out-of-band." The mask has the same protective effect either way.
- **Antenna manipulations and nearby metallic objects cannot significantly alter UWB emissions near the GPS bands.** XSI's antenna is printed on a rigid circuit board inside the case, and cannot be manipulated without breaking it. Even if antenna manipulation were possible, both theory and experiment show that neither it nor nearby metallic objects have any significant effect on GPS-band emissions. *In any event, the Commission will not certify a device that the user can easily take out of compliance.*
- **A suitable test for spectral lines eliminates the need even to consider whether a particular UWB device generates them.** A device capable of passing the spectral-line test does not generate spectral lines that could interfere with GPS. It is unimportant from a regulatory standpoint how the device accomplishes that. The Commission should follow its traditional approach of setting performance

---

<sup>3</sup> This reflects the most likely widespread application for very low power UWB communications devices.

<sup>4</sup> The specific test described in the attached letter is a modification of XSI's original proposal, to accommodate a request by GPSIC.

criteria, and letting industry decide how best to meet them.

- **GPS front-end filters cannot generate new spectral lines from UWB noise signals.** A filter cannot create signal out of noise. Incoming noise also comes out as noise, albeit shaped by the filter pass band.
- **Building materials, even in buildings whose outer surface is mostly glass, help to protect outdoor GPS from indoor UWB devices.** Even in a building that appears to be made entirely of glass, only a fraction of the exterior consists of window opening. The rest is exterior walls, support columns, and the spaces between floors. And even window glass impedes UWB signals unless the outdoor receiver is close to the glass, and lines up with the indoor transmitter at right angles. This combination is exceedingly unlikely.
- **UWB will not hinder indoor E911 assisted GPS.** Analysis shows that UWB emissions, at the levels proposed by XSI, will not cause harmful interference to indoor E911 assisted GPS even in the absence of other radio-frequency source. In a real-world indoor environment, radio noise from other sources (computers, fluorescent lights, motors, copiers, printers, elevators, etc.) will completely drown out the extremely faint UWB signal.

#### ADMINISTRATIVE LAW ISSUES

**Each of the regulatory measures proposed above is expressly contemplated in the NPRM, and thus can be implemented without a Further Notice.<sup>5</sup>** A Further Notice is legally and practically unnecessary, and would serve only to delay the introduction of a needed technology.

GPSIC is among the parties that requested a Further Notice in this proceeding.<sup>6</sup> But all of the proposed departures from the original NPRM are aimed at limiting UWB operation solely to protect GPS and certain other services. GPSIC and its allies have had their say, and indeed they were effective. But those parties cannot now use their own success in restricting UWB as the sole excuse to require another NPRM. Moreover, because all of the proposed departures were raised for discussion in the NPRM, the Administrative Procedure Act is fully satisfied.

---

<sup>5</sup> See NPRM at paras. 36-37 (spectral lines), 39 (emission mask), 43-44 (peak-to-average methods), 50 (measurement resolution bandwidth).

<sup>6</sup> Letter from Air Transport Ass'n of America, Inc., *et al.* to Chairman Michael K. Powell (May 18, 2001).

If there are any questions about this filing, please call me at the number above.

Respectfully submitted,

Mitchell Lazarus  
Counsel for XtremeSpectrum, Inc.

cc: Service List

***XtremeSpectrum, Inc. Response to  
U.S. GPS Industry Council ex parte filing of 21 June 2001***

**XTREMESPECTRUM, INC.  
8133 LEESBURG PIKE, SUITE 700  
VIENNA, VA 22182**

## TABLE OF CONTENTS

<b>1.</b>	<b>Introduction.....</b>	<b>3</b>
<b>2.</b>	<b>Aggregate Emissions from Multiple UWB Devices are Not a Significant Interference Threat to GPS.....</b>	<b>5</b>
<b>3.</b>	<b>The Spectral Mask Proposed by XSI is Appropriate for Control of UWB Emissions .....</b>	<b>7</b>
<b>4.</b>	<b>Antenna Manipulations Cannot Take a Well-Designed UWB Transmitter Out of Compliance .....</b>	<b>9</b>
<b>5.</b>	<b>A Test Using Narrow Resolution Bandwidth Will Prevent Interference from Spectral Lines .....</b>	<b>9</b>
<b>6.</b>	<b>GPS Front-End Filters Cannot Generate Spectral Lines From UWB Noise Signals .....</b>	<b>10</b>
<b>7.</b>	<b>Building Attenuation Helps to Protect GPS .....</b>	<b>10</b>
<b>8.</b>	<b>GPS-Assisted Approaches For E-911.....</b>	<b>12</b>
<b>9.</b>	<b>Conclusion .....</b>	<b>14</b>
	<b>APPENDIX A -- Antenna Characteristics.....</b>	<b>A-1</b>
	<b>APPENDIX B -- Test for Spectral Lines.....</b>	<b>B-1</b>

This filing by XtremeSpectrum (XSI) responds to *ex parte* submissions by the U.S. GPS Industry Council (GPSIC) on May 22 and June 21, 2001 that specifically address measures proposed by XSI to eliminate harmful interference to GPS.

XSI, with 64 employees, conducts research in ultra-wideband communications systems as its sole business. XSI intends to become a UWB manufacturer once the Commission authorizes certification of such systems.<sup>1</sup>

## 1. Introduction

XSI has recommended four measures more stringent than those proposed by the Commission, in order to assure that no harmful interference is caused to other users of the spectrum:

- An emission mask which rolls off more steeply below 2.7 GHz than the Commission's proposal,<sup>2</sup> and which offers more protection to GPS (see below);
- A restriction to indoor-only operation;<sup>3</sup>
- A test to reduce spectral lines in the GPS band (using a 10 kHz RBW; with a power limit 10 dB below the 1 MHz limit);<sup>4</sup> and
- An improved measure of peak-to-average ratio.

These measures are described in detail in XSI's filing of April 25, 2001.<sup>5</sup>

The recent GPSIC submissions question the feasibility of regulating UWB devices to prevent harmful interference to both conventional outdoor GPS and the possible indoor use of GPS in E-911 services. In raising these issues, however, GPSIC misapplies data and analyses from earlier stages of this proceeding. Since then, XSI and others have proposed measures in response to GPSIC's concerns.

XSI's response to GPSIC is summarized as follows:

- ***Aggregate effect.*** Analyses from multiple parties prove there is little aggregate effect from multiple UWB devices, even when they are concentrated in a small area such as a building. Signals from indoor UWB are subject to very rapid decay with distance, which prevents signals from devices spaced more than about 10 meters apart from adding significantly. Devices closer than about 10 meters necessarily share a single common RF channel, and so must reduce power, duty cycle, or both in order to function properly. *A GPS receiver sees less interference from an office building that houses hundreds of UWB*

---

<sup>1</sup> XtremeSpectrum takes no position on UWB radar applications.

<sup>2</sup> NPRM Para 39 suggests -12dB from Class-B below 2 GHz.

<sup>3</sup> This reflects the most likely widespread application for very low power UWB communications devices as short-range Wireless Personal Area Networks (WPAN). See NPRM at paragraphs 18 and 19; XSI comments at Sec. B.3 (filed Oct. 27, 2000).

<sup>4</sup> This is a modification of XSI's original proposal, to accommodate a request by GPSIC. See Section 5, below.

<sup>5</sup> XtremeSpectrum, Inc., Technical Statement on Reports Addressing Potential GPS Interference from UWB Transmitters, (filed April 25, 2001), section 2.

*emitters than from 2.5 full-time UWB emitters at the same distance as the nearest emitter.* Increasing the number of emitters in the building by tenfold, or even a hundredfold, does not change this result.

- ***Spectral mask.*** The impact of an interfering signal on a GPS receiver, and hence the efficacy of the spectral mask proposed by XSI, is unaffected by whether the UWB signal is “intentional” or “out-of-band.” Analyses previously filed in the record show that the rules proposed by XSI are appropriate and sufficient to protect GPS. Although it makes no substantive difference, XSI clarifies that it considers its emissions outside the -10 dB bandwidth to be out of band. XSI adopts 10 dB as the criterion for intentional emissions because the Commission proposes to use that level to define occupied bandwidth.<sup>6</sup> In the case of XSI’s modulation, the -10 dB bandwidth, which runs from 2.5 to 8 GHz, contains more than 97% of the total transmitted energy. Out-of-band emissions are a fact of life for all electronic devices, and are appropriately regulated by a spectral mask.
- ***Antenna manipulations.*** GPSIC’s concerns about untoward effects of antenna manipulations and nearby metallic objects are groundless. First, XSI’s antenna is printed on a rigid substrate and cannot be manipulated. Second, theory and measurements show that neither antenna manipulations nor nearby metal can realistically affect XSI’s UWB emissions near the GPS bands. Third, and most important, the Commission will not certify a device that the user can easily take out of compliance.
- ***Spectral line test.*** XSI originally proposed a spectral line test in the GPS band that used a 30 kHz resolution bandwidth (RBW), and called for an additional 15 dB of suppression below the levels specified for a 1 MHz RBW. GPSIC proposes instead that the Commission require a spectral line test using a 10 KHz RBW with 10 dB of suppression below 1 MHz RBW levels.<sup>7</sup> XSI accepts and endorses this alternative in lieu of its original proposal.
- ***Spectral line suppression.*** Adoption of a suitable test for spectral lines makes it unnecessary to consider whether a particular UWB design generates spectral lines, and if so, how it suppresses them. If a device passes the test, the Commission can be confident it does not generate spectral lines that could interfere with GPS. The design techniques used to accomplish this result are immaterial to the regulatory process. Indeed, the Commission has traditionally set its equipment standards in terms of performance criteria, and left industry free to decide how best to meet them.

---

<sup>6</sup> See NPRM paras. 21, 29 n.67.

<sup>7</sup> In its 21 June *ex parte* presentation, GPSIC notes in section 1 and in Table A.1 that an appropriate correction factor for CW-like emissions is -10 dB. This number is also supported by the published test results and analyses such as: (1) NTIA Special Publication 01-45, *Assessment Of Compatibility Between Ultrawideband Devices And Global Positioning Systems Receivers*, February, 2001, section 4.1.3, and (2) RTCA Paper No. 086-01/PMC-139, *Second Interim Report to the Department of Transportation: Ultra-Wideband Technology Radio Frequency Interference Effects to Global Positioning System Receivers and Interference Encounter Scenario Development*, RTCA SC-159, 27 MAR 2001, section 4.1.1.2

- **Effect of GPS filters.** GPS front-end filters cannot generate new spectral lines or other harmful interference from UWB noise signals. Noise going into a filter also comes out as noise, albeit shaped by the filter pass band.
- **Indoor UWB.** XSI has urged the Commission to restrict UWB communications devices to indoor use. A considerable body of engineering literature shows that building attenuation, even in buildings whose outer surface is mostly glass, helps to protect outdoor GPS from indoor UWB devices. Lists of references have been provided in numerous documents filed in this proceeding, and an additional list is included in this document.
- **Indoor GPS.** An analysis of indoor E911 assisted GPS (A-GPS) shows that, even in the absence of other RF sources, UWB emissions at the levels proposed by XSI will not cause harmful interference. In a real-world RFI environment, UWB emissions in the GPS bands will be literally lost in the noise.

The remainder of this document clarifies how XSI's proposed modifications to the rules satisfy all of GPSIC's concerns.

## 2. Aggregate Emissions from Multiple UWB Devices are Not a Significant Interference Threat to GPS

GPSIC continues to express concern that the aggregate emissions of multiple UWB devices will disrupt GPS receivers.<sup>8</sup>

Although interference power from multiple emitters will indeed add linearly in a victim system, as GPSIC asserts,<sup>9</sup> this fact must be applied in the context of plausible interference scenarios. For distributions of UWB devices over large regions, the emitters closest to a victim receiver dominate the interference effect for that particular receiver. On the average, the power received would be proportional to

$$\frac{1}{R_1^4} + \frac{1}{R_2^4} + \dots + \frac{1}{R_n^4}$$

(linear in addition) where  $R_n$  refers to the range to the  $n^{\text{th}}$  emitter, and the  $4^{\text{th}}$  power models typical energy decay with distance through the interior of a building due to attenuation and multipath from walls, floors, furniture, etc.<sup>10</sup> As a result, farther emitters will have a negligible contribution to the interference seen by the victim.

To illustrate the non-effect of aggregation, consider the example of an E911 handset in an office-building environment packed with a large number of nearby UWB wireless personal area networks (WPAN). A UWB WPAN provides about 10 meters coverage. Each WPAN typically consists of 2-16 devices, only one of which can be actively emitting at any one time. Table 1 shows how the power combines in the victim receiver for a hypothetical office-building example,

<sup>8</sup> Ex parte presentation of GPSIC at para. 5.0 (filed June 21, 2001).

<sup>9</sup> *Id.*

<sup>10</sup> Theodore S. Rappaport, *Wireless Communications, Principles and Practice*, Prentice Hall PTR, Upper Saddle River, NJ, pp85-90, 1996

and illustrates the fast decay in power, as UWB emitters get further away. Here, the first row (WPAN #1) represents a WPAN operating in the same room as the GPS receiver. Other rows represent multiple UWB WPANs operating in neighboring rooms throughout the building—242 WPANs in total. The WPANs are very tightly spaced to represent worst-case scenarios. Nonetheless, in this example, the total interference received by the victim is only 10% more than that of the first WPAN alone. For this example, we assumed:

- Every unit transmitting is operating at worst case, full power, levels. (i.e. 1.175 nW/MHz, which is -18dB below Part 15 Class B levels).
- For each WPAN, the UWB device closest to the GPS handset is the one transmitting at the time the handset initiates a GPS measurement.
- The closest WPAN has a transmitting device in the same room as the GPS enabled handset and we assign it only  $1/R^2$  propagation loss since it is line-of-sight.

The key point here is that more distant WPANs become insignificant. Aggregation is not an issue.

Table 1. Illustration of decay in power versus distance showing how aggregation is not an issue.

WPAN #	Range to Victim Receiver m	Power received by Victim Receiver picowatt/MHz	% of total energy received by victim receiver	Accumulated Power Received By Victim Receiver	Location of WPANs
1	3	0.029506	90.957	0.029506	Net in same room
2-18	7	0.001880	5.796	0.031386	17 Nets, 8 in adjacent rooms (left, right, above, below, left-above, right-above, left-below, right-below) PLUS 9 across the hall
19-50	11	0.000580	1.789	0.031966	32 Nets 16 in 2nd adjacent Rooms + 16 across hall
51-98	15	0.000252	0.776	0.032218	48 Nets, 24 in 3rd adjacent rooms + 24 across hall
99-162	19	0.000130	0.402	0.032348	64 Nets 32 in 4th adjacent rooms + 32 across hall
163-242	22	0.000091	0.280	0.032439	80 Nets 40 in 5th adjacent rooms + 40 across hall
<b>Total Interference = .032439 picowatts/MHz = -104.9 dBm/MHz = 1.099 times the power from the closest emitter</b>					

When emitters are more than about 10 meters apart, the signals decay drastically before reaching adjacent units, and so cannot add significantly. Thus, even though interference adds linearly, received interference does *not* increase linearly as UWB emitters spread over large regions. XSI has documented an analysis of these effects<sup>11, 12</sup> which are supported by other analyses and simulations presented in these proceedings.

Aggregations of UWB devices closer together (less than about 10 meters) also cannot cause significantly increased interference levels, although for different reasons. All of the devices in the same small area share a single common RF channel. Accordingly, they must coordinate their

<sup>11</sup> XtremeSpectrum, Inc., Comment of April 25, 2001: Technical Statement on Reports Addressing Potential GPS Interference from UWB Transmitters, section 5.

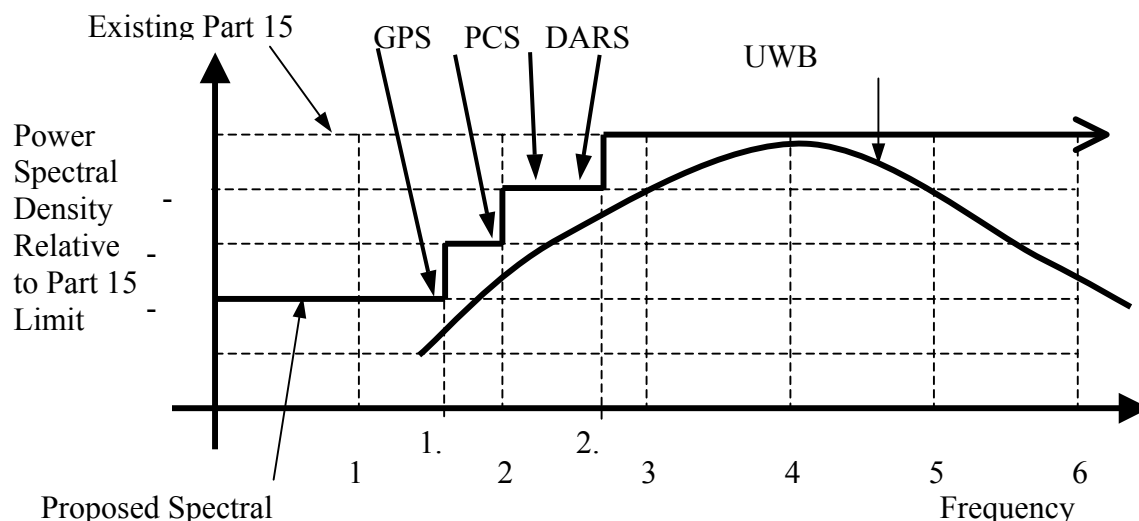
<sup>12</sup> Comment of Martin Rofheart (filed Dec. 8, 1998).

transmissions to avoid UWB-on-UWB interference. As emitter densities increase, the UWB system must decrease per-device operating power, operating time (duty cycle), or both, in order for the devices to communicate properly. The industry standard media access control (MAC) protocol now under development to cover UWB devices will require sharing the channel in discrete time slots, making it impossible for more than one unit to transmit at a time.<sup>13</sup>

GPSIC's fear of thousands of UWB emitters in a small area, all operating simultaneously at full power, simply cannot come to pass.

### 3. The Spectral Mask Proposed by XSI is Appropriate for Control of UWB Emissions

XSI proposed a spectral mask to protect other spectrum users in the regions below 2.7 GHz.<sup>14</sup> This curve is more stringent than the 12 dB reduction below 2 GHz proposed in the NPRM.<sup>15</sup> The XSI mask is specifically intended to reduce the lower frequency emissions of UWB devices, subject to the consideration that circuits cannot generate a "brick wall" response that takes the emissions abruptly to zero. XSI has demonstrated over several filings<sup>16</sup> that its proposed mask provides adequate protection to GPS and other services against harmful interference.



<sup>13</sup> See IEEE 802.15.3 protocol (targeting wireless personal area network devices such as UWB).

<sup>14</sup> This proposal predates NTIA Special Publication 01-45 on Global Positioning System Receivers. See Reply Comments of XtremeSpectrum, Inc. at 4 (filed Oct. 27, 2000).

<sup>15</sup> NPRM at paragraph 39.

<sup>16</sup> XSI reply comment, *XtremeSpectrum, Inc. Technical Statement on NTIA Report* (filed March 12, 2001) (Federal Systems); XSI comment, *Comment of XtremeSpectrum, Inc. on Issues of Interference into Global Position System Receivers* (filed April 25, 2001) (GPS); XSI comment, *Comments of XtremeSpectrum, Inc. on UWB/PCS Interference Issues* (filed April 25, 2001) (PCS); XSI reply comment, *XtremeSpectrum, Inc. Reply to Comments on Potential GPS and PCS Interference from UWB Transmitters* (filed May 10, 2001); (GPS and PCS); XSI ex parte letter, *XtremeSpectrum Technical Analysis of Possible Interference to the Satellite Digital Audio Radio Service from UWB Device Emissions* (filed June 5, 2001) (DARS).

GPSIC now questions the validity of the mask -- not on the basis of the protection it affords, but purely on the semantic basis of whether a mask can properly be applied to *intentional* emissions.<sup>17</sup>

The impact of an interfering signal on a GPS receiver, and hence the efficacy of the mask, is unaffected by whether the signal is intentional or out-of-band. The proposed mask has been shown to provide adequate protection to existing spectrum users, regardless of whether the frequencies it regulates are intentional or out-of-band, and is therefore appropriate for the regulation of UWB emissions.

GPSIC has consistently requested a -100 dBW/MHz limit in other proceedings.<sup>18</sup> In response, XSI proposed a mask that provides the protection that GPSIC had previously sought. In its latest filing, however, GPSIC suggests the proposed mask does not meet the protection requirements indicated in the RTCA report for precision aviation applications -- again, not on technical merit, but for the same reason as above: that masks should not be applied to intentional emissions. To support this position, GPSIC mischaracterizes the RTCA report as addressing out-of-band emissions (OOBE)<sup>19</sup>. In actuality, however, the RTCA report<sup>20</sup> does not specify whether interference is labeled as intentional or otherwise. Instead, it merely specifies the thresholds of interference, and then calculates the values that can be attributed to UWB sources (as one of many sources of interference) within the precision approach scenario. The link budget used by the RTCA includes the aeronautical safety margin, an allotment for multiple sources of noise, an allotment for multiple UWB emitters, and assumes no building loss. Even so, as GPSIC points out, the results of these worst case calculations (-100 dBW/MHz for CW spectra, -90 dBW/MHz for noise-like signals) are very close (within 0.7 dB) to the XSI's proposed spectral mask values. These facts are further evidence that the proposed mask is adequate and appropriate and reasonable.

Although it makes no substantive difference, XSI clarifies that it considers emissions outside the -10 dB bandwidth to be out of band. XSI adopts 10 dB as the criterion for intentional emissions because the Commission proposes to use that level to define occupied bandwidth.<sup>21</sup> In the case of XSI's modulation, the -10 dB bandwidth covers 2.5 to 8 GHz and includes 97% of the transmitted energy.

---

<sup>17</sup> Ex parte presentation of GPSIC at introduction and para. 1.0 (filed June 21, 2001).

<sup>18</sup> Reply comments of GPSIC in proceeding 99-67 (filed July 21, 1999) at 2 and Petition for Reconsideration by GPSIC in proceeding 99-168 (filed February 22, 2000) at 13.

<sup>19</sup> Ex parte presentation of GPSIC at para. 2.0 (filed June 21, 2001) Page 3 in "1.0 Spectral Mask" section.

<sup>20</sup> RTCA Paper No. 086-01/PMC-139, Second Interim Report to the Department of Transportation: Ultra-Wideband Technology Radio Frequency Interference Effects to Global Positioning System Receivers and Interference Encounter Scenario Development, RTCA SC-159 (March 27, 2001).

<sup>21</sup> See NPRM paras. 21, 29 n.67.

#### **4. Antenna Manipulations Cannot Take a Well-Designed UWB Transmitter Out of Compliance**

GPSIC states that UWB devices will likely have very little control over their own emitted power spectrum. GPSIC appears to have misinterpreted filings by Multispectral Solutions, Inc.<sup>22</sup> to imply that UWB systems have an inherent weakness that could result in modified emissions in the event of antenna deformation or proximity of metal objects.

The implication is incorrect. Like any other radio, UWB systems can control emissions by controlling the properties of the signal applied to the transmit antenna, the antenna structure, and its matching.

In any event, the XSI antenna is not susceptible to manipulation. The antenna is printed on a rigid circuit board inside the case, and is ordinarily inaccessible to the user. Any manipulation by the user that could deform the antenna will first break the substrate, making the radio unusable. Moreover, experimental results show the antenna characteristics are highly immune to nearby metallic objects. See Appendix A for details.

Finally, the Commission will refuse to certify a device that the user can easily take out of compliance by external manipulation.<sup>23</sup> GPSIC's concerns in this area are groundless.

#### **5. A Test Using Narrow Resolution Bandwidth Will Prevent Interference from Spectral Lines**

XSI has proposed a specific test to disqualify UWB devices that emit spectral lines in the GPS band. GPSIC counters that even sound design cannot eliminate spectral lines.<sup>24</sup> XSI disagrees; but the dispute is entirely moot. With adoption of a suitable test for spectral lines, it becomes unnecessary to consider whether a particular UWB design generates spectral lines, and if so, how it suppresses them. If a device passes the test, the Commission can be confident it does not generate spectral lines that could interfere with GPS. The engineering techniques used to accomplish this result are immaterial to the regulatory process.

XSI originally proposed a test using a 30 kHz RBW (resolution bandwidth), with emissions limited to 15 dB below the levels specified for a 1 MHz RBW. GPSIC proposes instead that the Commission require a test using a 10 KHz RBW with 10 dB of suppression below 1 MHz RBW levels.<sup>25</sup> XSI accepts and endorses this alternative in lieu of its original proposal.

GPSIC asks whether the spectral line will allow composite noise-and-CW signals to exceed the levels of the UWB spectral mask. Answer: it will not. A spectrum analyzer can measure only the composite power -- the total energy passing through its filter.

By way of illustration, consider a composite signal having both a wideband component of  $A$  watts/Hz), and a CW component of  $B$  watts. The spectrum analyzer, with its filter centered on

---

<sup>22</sup> Multispectral Solutions, Inc. (filed Sept. 12, 2000).

<sup>23</sup> Cf. 47 C.F.R. 15.15(b) (to qualify for certification, a device must be constructed so that adjustments to accessible controls cannot cause operation in violation of the rules).

<sup>24</sup> *Ex parte* presentation of GPSIC at para. 2.0 (filed June 21, 2001).

<sup>25</sup> See note 7.

the CW signal, would measure  $B+A*RBW$  watts. The measured power of the wideband components would be approximately 20 dB lower in a 10 kHz RBW than in a 1 MHz RBW, whereas the power in the CW component would be the same in both RBWs. This provides 20 dB more sensitivity to CW signals in the presence of a noise signals. Appendix B shows the results of using 1 MHz and 10 kHz RBW to measure composite noise plus tone signals. The results validate that the equations given above truly reflect reality. The proposed spectral line test guarantees the 10 dB extra protection needed against CW signals.

## **6. GPS Front-End Filters Cannot Generate Spectral Lines From UWB Noise Signals**

GPSIC asserts that the front-end filters of GPS receivers will cause the uncorrelated UWB pulses to become correlated, defeating any attempt to prevent spectral lines through modulation or UWB system design, and therefore leading to GPS interference.<sup>26</sup> This assertion is false.

The theoretical equations governing the operation of a filter prove it is impossible for a filter to generate new spectral lines. When noise goes into a filter, noise also comes out. Saying the output noise is “correlated by the filter” simply means the noise coming out has a different bandwidth, or different spectral shape, as modified by the filter’s differing response at different frequencies. For a CW line to come through the filter, the signal must have a CW line there to begin with (and the filter response must be non-zero at that frequency).

In the case of a stream of uncorrelated narrow UWB pulses, individual pulses may be lengthened and combined by the impulse response of the filter, but the output will just be the superposition of many uncorrelated, zero-mean pulses -- *i.e.*, noise. This result is identical to the effect of multipath. The presence of multi-path propagation components will lead only to the harmless superposition of uncorrelated zero-mean pulses. Neither multipath nor a filter can generate new spectral lines.

## **7. Building Attenuation Helps to Protect GPS**

GPSIC suggests the values proposed by NTIA (and used in XSI’s analysis) to account for building losses at GPS frequencies should be disregarded, because they do not account for walls that consist mostly of glass having low RF attenuation at GPS frequencies.<sup>27</sup> XSI has used the very conservative 9 dB attenuation figure supported by NTIA in its calculations,<sup>28</sup> even though realistic buildings have much higher losses.<sup>29</sup> The building attenuations used in NTIA’s analyses were based on a wide variety of studies, including its own in-house conducted surveys of

---

<sup>26</sup> *Ex parte* presentation of GPSIC at para. 2.0 (filed June 21, 2001)

<sup>27</sup> This conclusion by GPSIC’s is inconsistent with its claimed need to allow 20 dB or more attenuation to model GPS signals that propagate *into* buildings. *Ex parte* presentation of GPSIC at para. A.2 (filed June 21, 2001).

<sup>28</sup> National Telecommunications and Information Administration Special Publication 01–43, *Assessment Of Compatibility Between Ultrawideband Devices And Selected Federal Systems*, January, 2001, section 5.6.

<sup>29</sup> XSI has presented specifics to the Commission. See XtremeSpectrum, Inc. at slide 3 (filed May 30, 2001).

multiple building types, plus independent researchers, and the International Telecommunication Union Radiocommunication Sector (ITU-R) Study Group 3 on Propagation. The ITU-R study indicated the glass-to-brick ratio was 2:1 for buildings tested.

While window glass by itself is reasonably transparent to RF, this is significant only if (1) there is a line-of-sight path between the transmitter and receiver, (2) the receiver is located close to the glass, and (3) the RF path strikes the window surface at nearly a right angle. This required combination of circumstances is what prompts cell phone users to stand next to windows for better reception.

Buildings are not constructed of glass alone, even though they may be completely wrapped in it. Modern buildings often appear from the street to be made entirely of glass, but only a fraction of that is window opening. The glass facade also covers exterior walls, support columns, and the spaces between floors.

Moreover, De Toledo, *et al*, note that once a signal enters a building it encounters “a heterogeneous area of objects such as walls, ceilings, floors, furniture and equipment of many kinds. Such items present lossy shielding or reflection media to the RF signal and as a result, the signal experiences a varying degree of attenuation to which deterministic analysis cannot be applied.”<sup>30</sup> These effects produced 4–15 dB of penetration loss in their study of 6–9 story buildings, depending on the floor, with minimum loss near the 6<sup>th</sup> floor. (This height effect can most likely be attributed to the incident angle of the incoming signal, launched from the roof of another building). A number of papers<sup>31,32,33</sup> address these incident angle effects, and separate out external (and internal) material penetration losses from incident angle losses, which can average 20 dB at grazing. Davidson and Hill<sup>34</sup> made over 60,000 measurements at each of two

---

<sup>30</sup> A. de Toledo, *et al*. *Radio Propagation into buildings at 1.8GHz*, IEE Colloquium on University Research in Mobile Radio, 1990. pp.3/1-3/5

<sup>31</sup> J-E Berg, *Building Penetration Loss Along Urban Street Microcells*, Seventh IEEE Int’l Symp. On PIMRC, 1996, **3**, pp. 795-797. Average measured losses ranged from 5–30dB, with 4–10dB allotted to exterior wall effects, 4–10dB allotted to interior wall effects, and up to 20 dB for incident angle effects. Measurements were performed at 900 and 1700 MHz.

<sup>32</sup> R. Hoppe, *et al*, *Measurement of Building Penetration Loss and Propagation Models for Radio Transmission into Buildings*, IEEE 50<sup>th</sup> Veh. Tech. Conf. 1999, **4**, pp. 2298-2302. Measurements made at 1500 MHz showed average losses of 9.3–10.7 dB.

<sup>33</sup> H.Börjeson and B. De Backer, *Angular Dependency of Line-of-Sight Building Transmission Loss at 1.8 GHz*, Ninth IEEE Int’l Symp. on PIMRC, 1998, **1**, pp. 466–470. Measurements were made to separate out the loss due to penetration at 90° from that due to the off-normal incidence angle. Measurements near a window in a 44% glass building yielded 6.1 dB of loss in the normal case and 7–12 dB of loss at 30° to 60°. Another building had pairs of 0.9 m wide windows separated by a 0.5 m pillar. One window was removed and the loss measured at 90° was 5.9 dB through the opening and 6.0 dB at the pillar between the two windows. Losses normal to an exterior wall were 8.6 dB and the grazing angle loss term varied from 25.1–13.0 dB. Overall, the total loss for line-of-sight grazing incidence was an almost constant 28 dB.

<sup>34</sup> A. Davidson and C. Hill, *Measurement of Building Penetration Into Medium Buildings at 900 and 1500 MHz*, IEEE Trans. Vehicular Tech., **46**: 1, February 1997, pp.161–168.

frequencies for variety of locations in 10 medium sized buildings. The average loss was found to be 10.8 dB ( $\sigma=5.8$ ) at 900 MHz and 10.2 dB ( $\sigma=5.6$ ) at 1500 MHz. They describe the buildings as: "A large percentage of the [outer] building surface is glass, which is typical of the newer construction in the area".

The body of scientific literature shows that using 9 dB for an average building loss factor is not an overstatement, even when considering buildings with mostly glass exteriors.

## 8. GPS-Assisted Approaches For E-911

Three possible cases of interference into GPS need consideration: conventional outdoor GPS, and both outdoor and indoor E911 Assisted-GPS (A-GPS).

XSI analyzed the conventional outdoor case in a previous filing,<sup>35</sup> and showed that for noise-like signals, interference is much like that due to random broadband noise. This interference mechanism is well understood and well characterized. XSI showed that with good engineering practice it is possible to generate true noise-like signals. XSI showed that the proposed mask of 18 dB below Part 15 levels, while restricting UWB operations to indoors, was sufficient to protect GPS against noise-like signals in any reasonable situation. In addition, XSI proposed a spectral line test to detect signals to which C/A code GPS receivers are specifically sensitive.

In the case of an outdoor A-GPS E911, the receiver can take advantage of all the processing gain discussed by GPSIC<sup>36</sup> whenever the handset detects loss or reduction of signal. Assuming the Commission adopts XSI's proposals to restrict UWB communications devices to indoor operation (along with the proposed emission mask and GPS-band spectral line suppression test), GPS location capability outdoors will not be affected by UWB.

The A-GPS indoor case represents the most severe desired-RF and RFI environment for GPS receivers. Even in the absence of RFI, however, the threshold for successful GPS operations is *not* the receiver's noise floor, as GPSIC implies,<sup>37</sup> but instead is the processed carrier-to-interference ratio. To illustrate, a GPS receiver illuminated by the -130 dBm minimum signal, in full view of the sky and in the complete absence of any RFI, would find the signal, at the front-end before processing, 28.5 dB below its own thermal noise floor. GPS can nonetheless work in this environment, thanks to 43 dB of processing gain in the receiver. The assisted-GPS receiver extends this processing gain through a number of approaches to recover even more signal in marginal signal situations.<sup>38</sup>

Borrowing from the GPSIC UWB Interference Link Budget<sup>39</sup> we have calculated the carrier to noise margin for an indoor A-GPS receiver in the presence of UWB devices in Table 2.

---

<sup>35</sup> XtremeSpectrum, Inc., Technical Statement on Reports Addressing Potential GPS Interference from UWB Transmitters (filed April 25, 2001).

<sup>36</sup> Ex parte presentation of GPSIC at Appendix A (filed June 21, 2001).

<sup>37</sup> See *Id.* at para. A.5, table A.1.

<sup>38</sup> For example, see United States Patents 5,781,156; 5,812, 087; 5,841,396; and 5,874,914.

<sup>39</sup> Ex parte presentation of GPSIC at para. A.5, table A.1 (filed June 21, 2001).

8.1 Parameter	8.2 Budget	8.3 Comments
Minimum SV signal in clear, dBm	-130	GPS specification
Building penetration loss, dB	-9 – -20	NTIA and US GPSIC
GPS signal interior of building, dBm	-139 – -150	
Standard GPS processing gain, dB	43	
Detection margin, dB	-12	
Signal equivalent level, dBm	-108 – -119	
Assisted-GPS processing gain, dB	20–30	US GPSIC, FAA
Signal equivalent level, dBm	-78 – -99	
XSI limit @GPS freq, dBm/MHz	-59.3	18 dB below -41.3 dBm/MHz
Public Safety Margin, dB	0	Not defined for terrestrial applications
Multiple System Allotment, dB	0	Not defined for terrestrial applications
GPS antenna gain toward RFI, dB	0	
Separation distance, meters	3	Distance to closest emitter
Propagation loss, dB	-46	
Single emitter allotment	0.6	To account for multiple emitters. <sup>40</sup>
Bandwidth Correction factor, dB	3	GPS IF
UWB level at GPS receiver, dBm	-101.7	Noise-like signal. However, the 10 dB CW deficit is covered by the spectral line test
Carrier-to-noise margin	23.7–2.7	

**Table 2. Assisted-GPS E911 RFI Link Budget for a High Density Office Building**

The table shows that position determination would be possible from an A-GPS unit operating indoors in the vicinity of UWB devices, in the absence of any other RFI, with a signal-to-noise margin of 2.7–23.7 dB.

The table is based on the following assumptions:

The A-GPS processing gain values come from the GPSIC comment that performance is 20 dB better than standard GPS, and from the FAA studies.<sup>41</sup>

<sup>40</sup> Here a value of 0.6 dB is used to account for multiple emitters. Although all are assumed to operate at 100% activity factor and maximum power, we assume they are in separate offices. Since all emitters are at the same distance, here we use losses due to interior walls and floors to compute the equivalent signal. The loss through the wall to the adjacent office is assumed to be 9 dB. The loss through the ceiling/floor structure, along with its ductwork, vents, fluorescent light assemblies, electrical wiring, and sprinkler plumbing, is assumed to be 20 dB. This produces an aggregate power that is 0.6 dB above that of the single emitter in the room with the victim receiver. Even if the floor/ceiling loss is reduced to 9 dB, the aggregate sum is only 1.4 dB above the single emitter value.

<sup>41</sup> *Id.* At A.2. Also, FAA tests on pre- and post-processed data to improve interference performance of GPS systems have shown 20–30 dB improvement is possible. This is reported in *Test Results on Mitigation of SATCOM-Induced Interference to GPS Operation*, Mayflower Communications Company, Inc. and Federal Aviation Administration, ION GPS 1995, Palm Springs, CA, September, 1995.

We assume four UWB devices (on four different networks) within 3 meters of the A-GPS E911, with one is in the same room as the handset, as GPSIC assumed. We make the worst-case (and unlikely) assumption that all four UWB devices are running simultaneously at 100% duty cycle during the entire one-second period the A-GPS is storing data for processing.

GPSIC claims that UWB emissions must be 40–50 dB below existing Part 15 limits, because GPS-based E-911 systems need an environment that is “essentially interference free . . . at or below thermal noise.”<sup>42</sup> But that is impossible, with or without UWB. Any environment where UWB devices would potentially be used is not an RFI vacuum. A-GPS units used for E911, operating indoors, inevitably will be subject to interference not only from digital devices, like computers, but also from multiple and diverse sources such as fluorescent lights, motors, copiers, printers, elevators, TVs, etc. Communications devices using UWB will not operate in isolation, but rather in conjunction with other digital devices (desktops, laptops, PDAs, web-pads, etc.). These other devices are subject only to Class B limits. The UWB device itself is a conventional digital device, with CPU and standard digital input/output connections, with a UWB transmitter attached. Without the transmitter, the device need only satisfy the Class B requirements for digital devices. XSI’s proposal of a further 18 dB attenuation in the GPS bands makes the UWB emission insignificant relative to the multiple other sources of interference.

In short, under realistic assumptions, a particular E911 handset used indoors may or may not report its location successfully on a particular occasion; but either way, operation of UWB devices will not affect the outcome.

## 9. Conclusion

XSI has responded to the needs of the spectrum user community, particularly GPS, in proposing restrictions on UWB considerably more stringent than those originally advanced by the Commission. XSI advocates a mask that limits GPS-band UWB emissions to 18 dB below Section 15.209; indoor-only operation; a test to reduce GPS-band spectral lines by an additional 10 dB; and an improved measure of peak-to-average ratio. We have shown that these restrictions assure UWB does not cause harmful interference to other users, including GPS.

XSI’s product simulations actually show protection considerably beyond that indicated by the curve in Section 3. Such results are also predicted in the RTCA report (see figures A.4, A.6, A.11, and A.12 especially), where the energy in the GPS band is lowered by 37.8 dB.<sup>43</sup> These

---

<sup>42</sup> Ex parte presentation of GPSIC at para A.2 (filed June 21, 2001).

<sup>43</sup> RTCA Paper No. 086-01/PMC-139, Second Interim Report to the Department of Transportation: Ultra-Wideband Technology Radio Frequency Interference Effects to Global

levels are so low, however, that they are exceedingly difficult to measure in practice, because they tend to be masked by digital devices needed to connect with the UWB communications device. Even in the absence of other interference sources, UWB emissions at these levels will not significantly impact GPS, even indoors. In a real-world RFI environment, UWB emissions in the GPS bands will be literally lost in the noise.

---

Positioning System Receivers and Interference Encounter Scenario Development, RTCA SC-159, 27 MAR 2001, Appendix A.

## APPENDIX A -- Antenna Characteristics

GPSIC construes a filing by Multispectral Solutions, Inc. (MSSI)<sup>44</sup> to imply that UWB systems have an inherent weakness that could result in modified emissions in the event of antenna deformation or proximity of metal objects. This is incorrect.

### Antenna Deformations

Assuming a typically well matched antenna, deformations in the antenna cannot add to the total radiated power, but only change the strength in one direction relative to another. In fact, bending usually destroys the impedance matching and reduces the total radiated power. (In XSI's implementation, bending also breaks the substrate on which the antenna is printed and renders the radio inoperable.)

Furthermore, the UWB antennas used in indoor consumer electronics communication devices are electrically small and omni directional, with dipole-like patterns. Because their size is so small relative to the wavelengths involved, electromagnetic theory says they cannot be made highly directive no matter how they are bent.<sup>45</sup> In XSI's device, not only does the antenna exhibit a good impedance match and very stable transfer function, but the power in the signal going to the antenna is peaked in the desired passband, and drops on either side of it, just as in a traditional narrowband radio. In support of the theory, the XSI device constitutes an existence proof that UWB devices can, in fact, have very good control over their emitted power spectrum.

The MSSI test<sup>46</sup> cited by GPSIC was meant to suggest that the FCC might want to regulate the spectrum of the signal going into the antenna, as opposed to regulating only the radiated signal energy. It was never meant to imply that UWB systems necessarily had uncontrollable emissions.

### Nearby Metallic Objects

Tests on UWB antennas confirm they are highly immune to nearby objects. Below, we report on antenna tests performed by XSI using a vector network analyzer, with various metal objects as close as 1 inch from the antenna. These tests demonstrate expected multipath effects, but no antenna detuning even when metallic objects are placed so close to the transmit antenna that they would be obtrusive to the user. These tests prove that UWB antennas can achieve very good control of emissions and are not necessarily subject to significant changes in power spectrum due to proximity of metal objects.

MSSI's conclusion that an *arbitrary* metal sheet, likely to be "*near*" the antenna, will *always* severely influence the spectrum is wrong. The metal MSSI used to reach this conclusion was far from arbitrary. It also had to be so close to the antenna as to degrade the system performance, which would make the configuration unacceptable to a user.

MSSI made tests with and without "nearby metal." To have any effect, the "nearby metal" had to be carefully designed -- exactly the right size to be tuned as a director, and in exactly the right

---

<sup>44</sup> Multispectral Solutions, Inc. (filed Sept. 12, 2000).

<sup>45</sup> See, for example, Chapter 11, "Antenna Fundamentals", in *Electromagnetic Waves and Radiating Systems*, by Jordan and Balmain, Prentice-Hall, Inc. 1968

<sup>46</sup> Multispectral Solutions, Inc. at Figure 3 (filed Sept. 12, 2000).

position to act as a director (just as Yagi-Uda antenna arrays must be carefully designed for director and reflector sizes and driven element tuning). Furthermore, the MSSSI configuration improved the match at a lower “detuned” frequency, right where the applied signal had more energy. The waveform used had approximately 10 dB more power available in the GPS band than it did at 3 GHz, and even more energy as the frequency went lower. These tests emphatically do *not* support the general conclusion that arbitrary metal at other distances would always have similar effects. Our own tests, described below, show that nearby metal ordinarily has *no* significant effect.

It is true that constructing a UWB system using video (unipolar) pulse excitation of the antenna, where the watts/Hz in the signal rises roughly as the 1/frequency, can make the system more sensitive to antenna modifications. Nonetheless, no metal objects can ordinarily be close enough to the antenna, at just the right size and in just the right position, to have even a potential effect. To the contrary, experience shows that any metal close enough to have an effect will degrade performance and *reduce* the emissions.

XSI conducted tests specifically to show the lack of sensitivity of a UWB antenna to local metal objects. The antenna used represents a real marketable device. It is a consumer electronics antenna that fits into a compact-flash device, and is etched onto the same low-cost substrate that holds the UWB radio integrated-circuit chip set.

Although placing metallic objects in the vicinity of an antenna can influence its directive characteristics -- corner reflectors and reflecting screens located behind dipole or bowtie type antennas, as well as directors in Yagi-Uda arrays, are used for this purpose -- the directivity typically exhibits frequency selectivity that is detrimental to UWB systems. As a result, UWB units operate best with antennas that are insensitive to local objects and that are operated away from close metal.

The results shown in Figures A1 and A2 were measured using a Rohde & Schwarz ZVM Vector Network Analyzer (VNA) in an office building room, and therefore contains multipath from the room in addition to perturbations from the 3” by 6” steel plate that was used to perturb the antenna. The first plot shows the S21 (the forward transfer ratio) (i.e. the impulse response between two antennas) with the transmitting and receiving antennas in the clear (i.e. metal plate far away) and with a metal plate located behind the antenna at a distance of 1”. The second plot shows the spectral directivity with a metal plate at 4”. These extremely close distances could not arise inadvertently.

A diamond in each plot notes the location of GPS L1. The antenna response at L1 is virtually unchanged as the metal plate is moved. GPS L2 and L5 are located even lower in frequency, with even smaller responses.

In short, even metal objects so close to the antenna as to be obtrusive to the user have a negligible effect on the radiated emissions. This conclusion is supported by the fact that objects further than a wavelength away are sufficiently decoupled from the antenna that they have little impact on tuning, and merely represent a multipath scatterer.

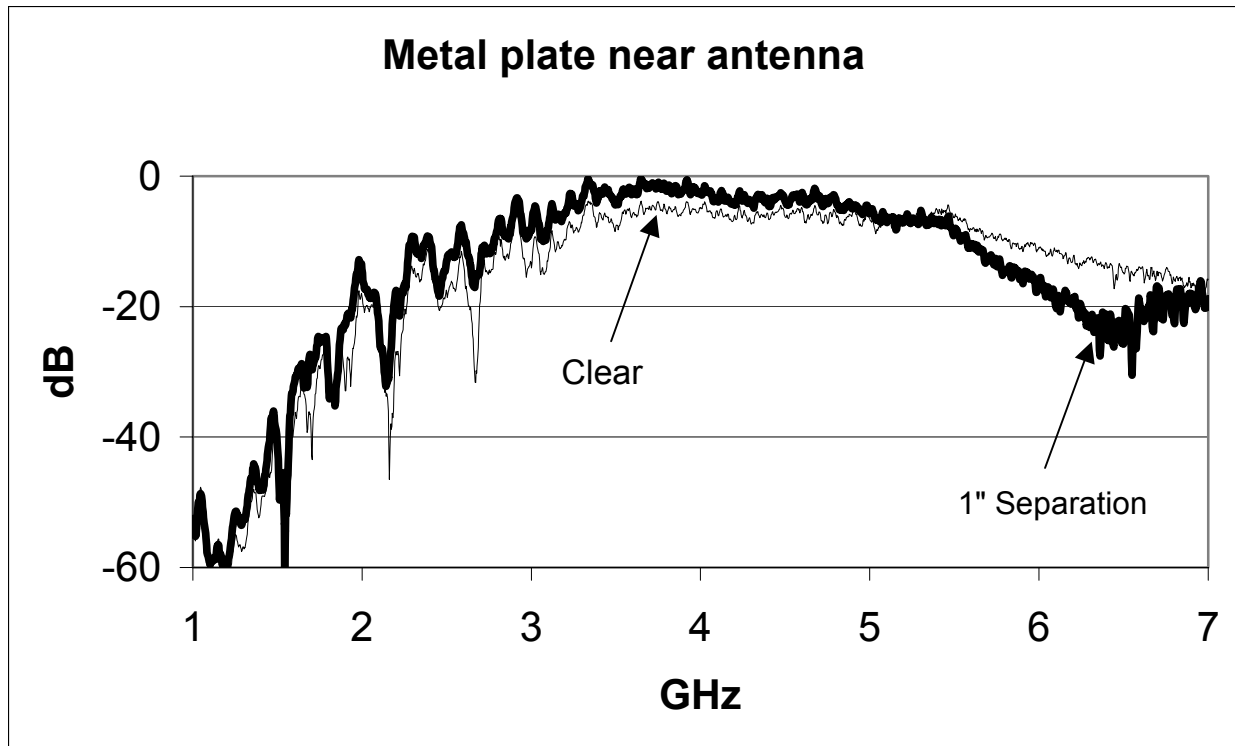


Figure A1. Comparison of antenna response with and without a plate 1" from the antenna.

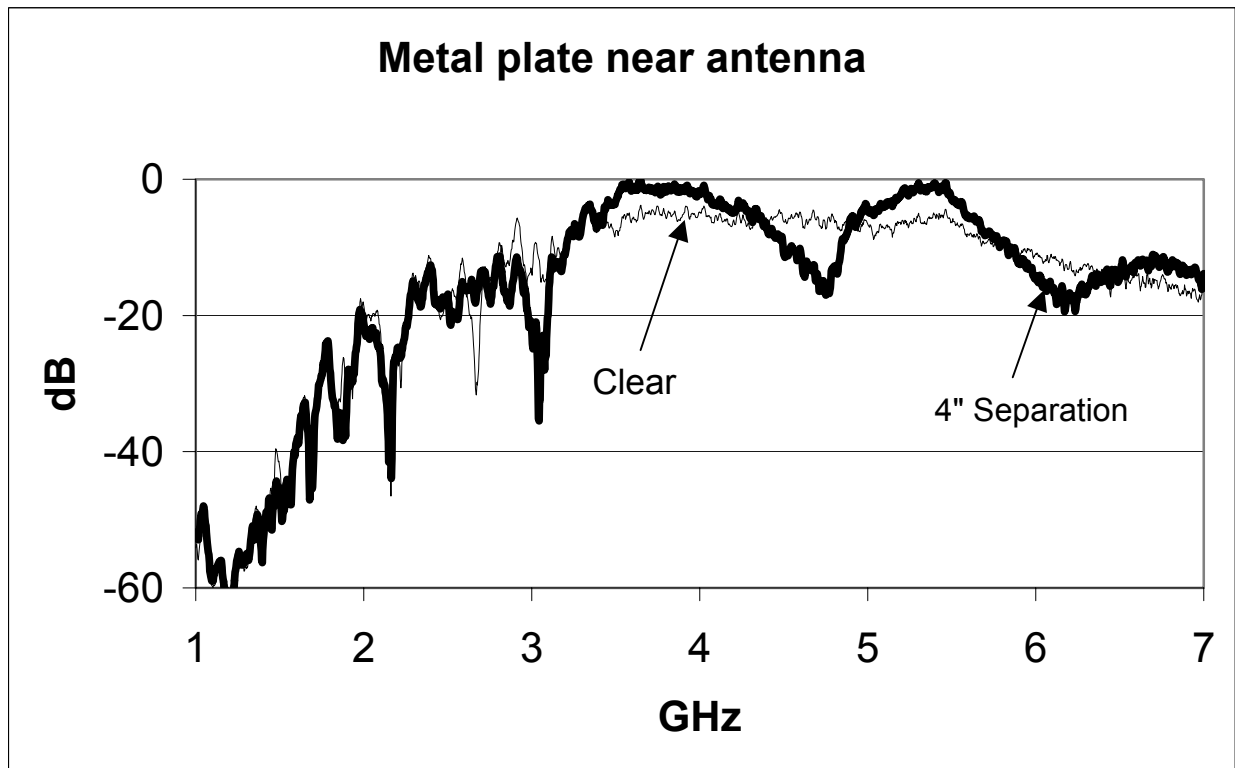


Figure A2. Comparison of antenna response with and without a plate 4" from the antenna.

## APPENDIX B -- Test for Spectral Lines

This appendix demonstrates the capability of the proposed spectral line test to identify and measure spectral lines below the noise. Such a measurement is displayed in Figure B1 taken with a Rohde & Schwarz ESI-26 EMI test receiver/spectrum analyzer. Here, a composite signal is being measured where the CW part of the signal is ~10 dB less than the 1 MHz RBW noise-like part of the signal. In the 1 MHz RBW trace (upper blue line) a slight bump is noticeable in the vicinity of the CW signal (due to the fact that the powers add). The highest power level is observed at 1.575 GHz. Without the spectral line test, but applying the proposed additional 18 dB protection mask below 1.6 GHz, this point would have to meet a -59.3 dBW/MHz level. The “bump” due to the tone would force the noise component to be 0.458 dB lower than the -59.3 dBm/MHz specification, in order to meet the regulatory limit. When a spectral line test is performed using a 10 kHz RBW, the CW “tone” is readily visible because the noise component has dropped by 20 dB. In fact, because of the additive nature of the noise and CW powers, a -10 dB tone appears 0.374 dB higher than it actually is, as shown in Table B1. It is clear from these measurements that a CW signal 10 dB below the broadband-noise is easily identified and limited.

TABLE B1. Illustration of additive nature of composite (noise plus tone) signals.

Reduction in allowed noise level in 1 MHz RBW due to additive affect of tone	-0.458	dB				
	Reduction from Class-B	dBm	pico watts	sum pico watts	dBm	Excess in tone measurement due to noise component
tone	18+10	-69.30	117.5			
1 MHz RBW Noise	18+.458	-59.76	1057.3	1174.8	-59.30	
30 kHz RBW Noise		-74.76	33.4	150.9	-68.21	1.088
10 kHz RBW Noise		-79.76	10.6	128.1	-68.93	0.374

There was some question about what happens if the “spectral line” is changing frequency with data modulation, since the line is now spread some. Technically, if the “line” is modulated, then it is not truly a spectral line. Nonetheless, as long as its energy fits within the RBW of the spectrum analyzer, the measurement result would be identical, because the analyzer measures whatever energy is passing through its RBW-wide filter.

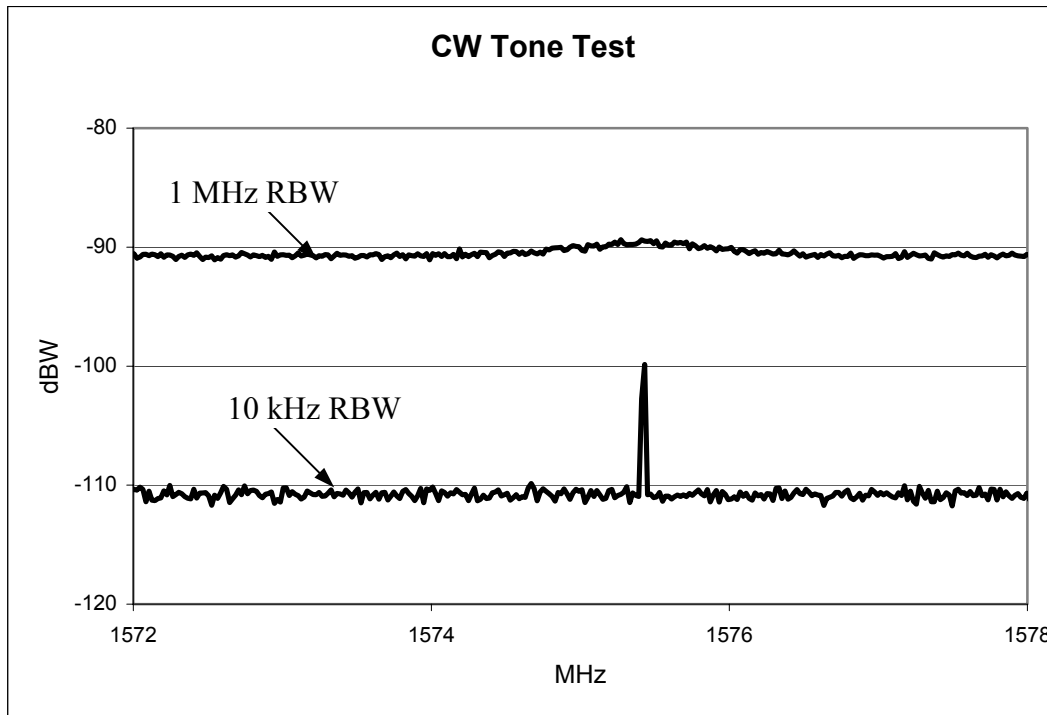


Figure B1

## **SERVICE LIST**

Chairman Michael Powell  
Federal Communications Commission  
445 12<sup>th</sup> Street, S.W.  
Washington, D.C. 20554

Commissioner Gloria Tristani  
Federal Communications Commission  
445 12<sup>th</sup> Street, S.W.  
Washington, D.C. 20554

Commissioner Kathleen Q. Abernathy  
Federal Communications Commission  
445 12<sup>th</sup> Street, S.W.  
Washington, D.C. 20554

Commissioner Michael J. Copps  
Federal Communications Commission  
445 12<sup>th</sup> Street, S.W.  
Washington, D.C. 20554

Commissioner Kevin J. Martin  
Federal Communications Commission  
445 12<sup>th</sup> Street, S.W.  
Washington, D.C. 20554

Bruce Franca, Acting Chief  
Office of Engineering and Technology  
Federal Communications Commission  
445 12<sup>th</sup> Street, S.W., Room 7C-155  
Washington, D.C. 20554

Julius P. Knapp, Deputy Chief  
Office of Engineering & Technology  
Federal Communications Commission  
445 12<sup>th</sup> Street, S.W., Room 7B-133  
Washington, D.C. 20554

Rebecca Dorch, Deputy Chief  
Office of Engineering & Technology  
Federal Communications Commission  
445 12<sup>th</sup> Street, S.W.  
Washington, D.C. 20554

Dr. Michael Marcus  
Associate Chief of Technology  
Office of Engineering & Technology  
Federal Communications Commission  
445 12<sup>th</sup> Street, S.W.  
Washington, D.C. 20554

Karen E. Rackley, Chief  
Technical Rules Branch  
Federal Communications Commission  
445 12<sup>th</sup> Street, S.W., Room 7A-161  
Washington, D.C. 20554

John A. Reed  
Senior Engineer  
Technical Rules Branch  
Office of Engineering and Technology  
Federal communications Commission  
445 12<sup>th</sup> Street, S.W., Room 7A-140  
Washington, DC 20554